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Componential Interpretation of the General Factor in Human Intelligence

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This chapter presents a componential interpretation of the general factor in human intelligence. The article is divided into five parts. First, we present a brief summary of some of the evidence that can be adduced in support of the existence of a general factor in human intelligence. Second, we present an overview of our beliefs regarding the nature of g, and state why we believe it is adequate to the problem, at least at one level of analysis. Third, we describe our present research approach. Fourth, we present evi-

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A Componential Interpretation of the General Factor

in Human Intelligence

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A Componential Interpretation of the General Factor

in Human Intelligence

Every since Spearman's (1904, 1927) proposal of a general factor per-

meating all aspects of intelligent behavior, theorists of intelligence have

busied themselves trying either to prove or disprove the existence in the

mind of Spearman's "g." No doubt this popular pursuit will continue, if

only because it provides a way of filling time for those who have had

trouble finding other pursuits that strike their fancy.

We interpret the preponderance of the evidence as overwhelmingly sup-

porting the existence of some kind of general factor in human intelligence.

Indeed, we are unable to find any convincing evidence at all that militates

against this view. We shall present here only a cursory examination of the

main findings that lead us to accept the existence of a general factor, since

careful and thorough reviews of the documentation exist elsewhere (e.g.,

Eysenck, 197.; Humphreys, 1979; McNemar, 1964). For the most part, we shall

assume that a general factor exists, and proceed to what we believe to be

the interesting question facing contemporary theorists of intelligence: What

is the nature of the general factor? In particular, we shall attempt to under-

stand g in information-processing terms, applying a metatheoretical framework

we refer to as a "componential" one in our attempt to isolate the information-

processing origins of g. This framework has been used with at least some suc-

cess in the analysis of a variety of different kinds of intelligent behavior

(see Sternberg, 1977b, 1978a, 1979, 1980b, 1980c, in press-c, in press-e).

We certainly do not wish to claim that the componential framework is the only

one in which general intelligence potentially can be understood: Any pie can

be sliced in a number of ways, and the best we can hope for is that our way

of slicing the pie yields pieces of a reasonable size and shape.

Our presentation is divided into five parts. First, we present a brief summary of some of the evidence that can be adduced in support of the existence of a general factor in human intelligence. Second, we present an overview of our beliefs regarding the nature of g as understood in componential terms. Third, we describe the research approach we use to tackle the problem of the nature of g, and state why we believe it is adequate to the problem, at least at one level of analysis. Fourth, we present evidence that supports our views regarding the nature of g. Fifth and finally, we summarize the main points of our argument.

Selected Evidence Supporting the Existence of General Intelligence

Various sorts of evidence have been adduced in support of the existence of general intelligence (Humphreys, 1979). Perhaps the most persuasive evidence is everyday experience: Casual observation in everyday life suggests that some people are "generally" more intelligent than others. People's rank orderings of each other may differ according to how they define intelligence, but some rank ordering is usually possible. Moreover, when people are asked to characterize the behaviors that typify a "generally" intelligent person, they have no trouble in doing so, and there is a high degree of consistency both in the sorts of behaviors that are listed and in the perceived relationships among these behaviors, as ascertained by factor analysis (Sternberg, Conway, Ketron, & Bernstein, 1980). Very similar factor structures are obtained both for experts and laypersons: A generally intelligent person is conceived to be one who is particularly adept at the behaviors constituting problem solving, verbal facility, and common sense in interactions with the real world.

Historically, the evidence that has been offered most often in favor of

the existence of general intelligence is the appearance of a general factor
in unrotated factor solutions from factor analyses of tests of intelligence
(e.g., Spearman, 1927). Other factor-analytic techniques, such as second-
order factoring of first-order factoring, can also yield a general factor.
(See Jensen, in press, for a discussion of various factorial methods for
eliciting a general factor.) In earlier research on the nature of mental
abilities (e.g., Thurstone, 1938), and in some contemporary research as well
(e.g., Guilford, 1967; Guilford & Hoepfner, 1971), the general factor seems
to disappear because of the way in which the factorial axes are rotated.
For example, a general factor almost never appears when axes are rotated
to Thurstonian "simple structure" (Thurstone, 1947). But when correlated
simple-structure factors are themselves factored, a general factor usually
appears at the second order of analysis.

Many theorists of intelligence no longer view the debate over whether
or not there is a general factor as still viable. Instead, they accept
some kind of hierarchical structure of mental abilities whereby intelligence
is viewed as comprising a general factor at the highest level, major group
factors such as fluid and crystallized abilities (Cattell, 1971; Horn, 1968)
or practical-mechanical and verbal-educational abilities (Vernon, 1971) at
the next level, minor group factors at a third level, and specific factors
at a fourth level. What had seemed like conflicting views at one time, then,
are now seen by these theorists, including ourselves, as basically compatible
(Snow, 1979; Sternberg, in press-a, in press-e). Accepting this point of
view, we can turn to the question of what kinds of entities generate indi-
vidual differences in performance at the highest level of the hierarchy,
that of general intelligence.

Were factor-analytic evidence the only kind that lent support to the existence of a general factor, one might write off the general factor as a method-specific peculiarity deriving somehow either from the mathematical mechanics of factor analysis or from the particular nature of individual-differences data. If one delves into the nature of variation across stimulus types rather than across subjects, however, a result parallel to the general factor emerges. A number of investigators, including ourselves, have used multiple regression techniques to isolate sources of stimulus variation in task performance. For example, we have attempted to predict response times to answer various kinds of analogies on the basis of manipulated sources of task difficulty in the solution of the analogies, e.g., the degree of related-ness between the first two terms, the degree of relatedness between the first and third terms, and so on (see Sternberg, 1977a, 1977b). A result that at first glance appears most peculiar has emerged from many of these task analyses (Egan, 1976; Hunt, Lunneborg, & Lewis, 1975; Jensen, 1979; Keating & Bobbitt, 1978; Mulholland, Pellegrino, & Glaser, 1980; Sternberg, 1977a, 1977b): The regression intercept, or global "constant," often turns out to be as highly correlated or more highly correlated with scores from IQ tests than do the ana-lyzed parameters representing separated sources of variance. Since the constant includes speed of response, e.g., button pressing, one could interpret such results trivially as indicating that motor speed is an essential ingredient of intelligence. A more plausible interpretation, and, as it will turn out, one more consistent with the bulk of the data, is that there are certain constancies in information-processing tasks that tend to be shared across wide variations in item types. We suggest that the search for the general component(s) and the search for the general factor are one and the same search--that whatever it is that leads to a unitary source of individual differences across subjects also leads to a unitary source of differences across stimulus types.

What is General Intelligence?

On the componential view, the basic construct underlying intelligent
functioning is the information-processing component. A component is an
elementary information process that operates upon internal representations
of objects or symbols (Sternberg, 1977; see also Newell & Simon, 1972).
The component may translate a sensory input into a conceptual representa-
tion, transform one conceptual representation into another, or translate
a conceptual representation into a motor output. What is considered
elementary enough to be labeled a component depends upon the level of theo-
rizing that is desired. Just as factors can be split into successively
finer subfactors, so can components be split into successively finer sub-
components. Thus, no claim is made that any of the components referred
to later are elementary at all levels of analysis. Rather, they are claimed
to be elementary at a convenient level of analysis. The same caveat applies
to the typology of components that will be proposed. Doubtless, other typolo-
gies could be proposed that would serve the present or other theoretical
purposes as well or better. The particular typology proposed, however, has
proved to be convenient in at least certain theoretical and experimental contexts.
A number of theories have been proposed during the past decade that might be
labeled, at least loosely, as componential (e.g., Butterfield & Belmont, 1977;
Campione & Brown, 1979; Carroll, 1976, 1980; Hunt, 1978; Jensen, 1979; Pelle-
grino & Glaser, 1980; Snow, 1979). The present theory, then, is just one of
this general class of theories, although it is probably a bit more elaborated
than at least some of the other theories.

Properties of Components

Each component has three important properties associated with it: duration,
difficulty (i.e., probability of being executed erroneously), and probability of

execution. Methods for estimating these properties of components are described in Sternberg (1978b) (see also Sternberg, 1977b, 1980b; Sternberg & Rifkin, 1979). It is dangerous to make inferences about one property of a component on the basis of information about another. We have found, for example, that the duration of a component is not necessarily correlated with its difficulty (Sternberg, 1977a, 1977b, 1980b).

Kinds of Components

Kinds of components can be classified in two different ways: by function and by level of generality.

Function. Components perform (at least) five kinds of functions. Meta-components are higher-order control processes that are used for executive planning and decision-making in problem solving. Performance components are processes that are used in the execution of a problem-solving strategy. Acquisition (or storage) components are processes used in learning new information. Retention (or retrieval) components are processes used in retrieving previously stored knowledge. Transfer components are processes used in generalization, that is, in carrying over knowledge from one task or task context to another. Generally speaking, metacomponents act on other kinds of components (and on themselves), whereas performance, acquisition, retention, and transfer components act on information of various kinds.

Level of generality. Components can be classified in terms of three levels of generality. General components are required for performance of all tasks within a given task universe. Class components are required for performance of a proper subset of tasks that includes at least two tasks within the task universe. Specific components are required for the performance of single tasks within the task universe. Tasks requiring intelligent performance differ in the numbers of components they require for completion and in the number of each kind of component they require.

Components and General Intelligence

To communicate early on the conclusion we will reach from an evaluation of the data we have collected, we assert here that individual differences in general intelligence can be attributed in part to individual differences in the effectiveness with which general components are performed. Since these components are common to all of the tasks in a given task universe, factor analyses will tend to lump these general sources of individual-differences variance into a single general factor. As it happens, the metacomponents have a much higher proportion of general components among them than do any of the other kinds of components, presumably because the executive routines needed to plan, monitor, and possibly replan performance are highly overlapping across tasks of a widely differing nature. Thus, ·individual differences in metacomponential functioning are largely responsible for the persistent appearance of a general factor in mental-test data.

Metacomponents are probably not solely responsible for "g," however. Most behavior, and probably all of the behavior exhibited on intelligence tests, is learned. There may be certain acquisition components general across a wide variety of learning situations, which also enter into the general factor. Similarly, components of retention and transfer may also be common to large numbers of tasks. Finally, certain aspects of performance—such as encoding and response—are common to virtually all tasks, and they, too, may enter into the general factor. Therefore, although the metacomponents are primarily responsible for individual differences in general intelligence, they are almost certainly not solely responsible. Acquisition, transfer, retention, and performance components that are general across tasks also can be expected to contribute to individual differences in the general factor underlying intelligent performance.

In th⁺ second part of the chapter, we have given a very compact view

of the nature of components and of how components enter into general intel-

ligence. We proceed now to describe in some detail the methods of two

as yet unpublished experiments addressed primarily to the question of what

is general intelligence (Sternberg & Gardner, 1980), and then describe

more briefly other experiments upon which we shall draw that also address

this question (Sternberg, 1977a; Sternberg & Nigro, 1980; Sternberg & Rifkin,

1979; Sternberg & Salter, 1980).

Some Experimental Paradigms for Isolating the

Information-Processing Origins of General Intelligence

We have conducted a number of experiments that have led us to the views

described in the preceding part of the chapter. In terms of our present

exposition, two particular experiments have been central to our conceptualizations,

and several other experiments have been peripheral to these conceptualizations.

The "Central" Paradigm

The basic problem we confronted is that of isolating the information-

processing origins of the general factor in human intelligence. Our basic

strategy was to (a) select items that have been shown in the past to be excel-

lent measures of g; (b) model response choices and response times in each of

these items; (c) examine what emerged as common across the models and the

tasks; and (d) propose an information-processing account of g on the basis

of the observed communalities (Sternberg & Gardner, 1980).

In most psychometric investigations of intelligence, the psychometric

technique upon which the investigation has been based has been factor

analysis. In such investigations, a representative sample of subjects from

a population of interest would be given a range of tests sampling a wide

variety of mental abilities, such as vocabulary, analogies, spatial visualiza-

tion, classification, memory, and word fluency; then, an intercorrelation matrix would be computed between all possible pairs of these tests; next, the intercorrelation matrix would be factor analyzed to yield hypothesized latent sources of individual differences in the observable test scores; finally, interpretations would be assigned to these factors on the basis of the clusters of tests that showed high or low loadings on the various factors.

In our investigation of general intelligence, we also drew heavily upon a psychometric technique for analysis of the data. The technique we used was nonmetric multidimensional scaling rather than factor analysis, however (see Kruskal, 1964a, 1964b; Shepard, 1962a, 1962b, 1974). In our use of this technique, the goal was to discover the dimensions underlying a hypothetical semantic space comprising names of mammals, such as "lion," "tiger," "giraffe," "beaver," "donkey," and "rabbit." In a typical multidimensional-scaling study, subjects are asked to rate the similarity (or dissimilarity) between all possible pairs of terms to be scaled, which, in our case, was 30 mammal names. Next, a proximity matrix is formed comprising the mean rated similarity (or dissimilarity) of each term to every other term. It is usually assumed in advance that the matrix is reflexive (i.e., that the dissimilarity between a term and itself is zero), symmetrical (i.e., that the dissimilarity between one term and another is equal to the dissimilarity between the second term and the first), and that the triangle equality is satisfied (i.e., that if the distance between a first term and a second term is large, and the distance between that first term and a third term is large, then the distance between the second term and the third term is also large). Then, the multidimensional scaling algorithm is applied to the similarity or dissimilarity data, using only ordinal properties of the data, and yielding a psychological space comprising underlying dimensions of relationship among stimuli. Finally, the

dimensions are interpreted on the basis of clusters of stimuli that have high or low loadings on each of the dimensions.

We were spared the need of actually doing the scaling ourselves by the fact that it had been done earlier on the set of mammal names by Henley (1969), who used a variety of different measures of relationship as input to the scaling algorithm and found striking consistencies in the outcome space without regard to the measure of relationship used. Henley found that the relations among mammal names could be captured very well by a three-dimensional spatial solution, with dimensions of size, ferocity, and human-ness. For example, a gorilla would have a high loading on all three of these dimensions, whereas a beaver would have a low loading on all three. Henley used orthogonal dimensions in her solution, so that for the total set of mammal names, there was no correlation between loadings on pairs of dimensions.

We used the mammal names from the Henley (1969) scaling of proximity data to form 30 mammal-name analogies, series completions, and classifications. The analogies were taken from Rumelhart and Abrahamson's (1973) study of analogical reasoning with mammal names; the classifications and series completions were of our own construction. In Experiment 1, we administered each item untimed in four-choice, multiple-option format, with the subjects' task to rank-order each of the options in terms of its goodness of fit as a possible solution. In Experiment 2, we administered the same items, retaining just two of the four options; in this experiment, subjects were asked to select the better option as rapidly as they could. Examples of items are shown in Table 1. Subjects in the two experiments were 30 and 36 (different) college undergraduates respectively; obviously, our subject pool was not representative of the general population (in this or any of our experiments). Subjects received the three reasoning tasks in counterbalanced order, and then received a set of mental ability tests stressing reasoning abilities.

Insert Table 1 about here

The "Peripheral" Paradigms

Sternberg (1977a) administered schematic-picture, verbal, and geometric analogies tachistoscopically to Stanford undergraduates. The first two kinds of analogies were presented in true-false format; the last kind was presented in forced-choice format. The analogies were standard in form (A : B :: C : D, where D could be either a true or false completion or one of two answer options), and were easy enough to allow almost error-free performance in the subject population.

Sternberg and Nigro (1980) administered verbal analogies to 20 students in each of grades 3, 6, 9, and college. The college students were Yale undergraduates; the other students were public-school students from a middle-class suburb of New Haven. All subjects received the same 180 verbal analogies in which vocabulary level was restricted to grade 3 or below according to the Thorndike-Lorge norms. Analogies were presented in three formats differing in the numbers of terms in the analogy stem versus in the analogy options. Specifically, the number of terms in the analogy stem could be either three, two, or one. The remaining terms were options. Consider an example of each format: (a) NARROW : WIDE :: QUESTION : (trial) (statement) (answer) (task); (b) WIN : LOSE :: (dislike : hate) (ear : hear) (enjoy : like) (above : below); (c) WEAK : (sick :: circle : shape) (strong :: poor : rich) (small :: garden : grow) (health :: solid : firm). Each option appeared on a separate line of print. Numbers of answer options varied from two to four. Items were presented tachistoscopically, and subjects were told to respond as quickly as possible.

Sternberg and Rifkin (1979) administered schematic-picture analogies to between 15 and 21 parochial-school children in each of grades 2, 4, and 6, and college-level adults at Yale. Analogies were presented in forced-choice format in 24 test booklets, each containing 16 analogies composed of binary attributes

including height (tall, short), garment color (black, white), sex (male, female),
and weight (fat, thin) (as in Sternberg, 1977a). Items within each of the
24 booklets were homogeneous in terms of the number of attributes varied from
the first term to the second, from the first term to the third, and between
the two answer options. Since identities of actual values on attributes
varied across analogies, however, no two analogies were identical. Each
booklet was timed for 64 seconds. The main dependent variable, solution
latency for items correctly answered, was computed by dividing 64 by the
number of items correctly completed in a given booklet.

Sternberg and Salter (1980) (see also Sternberg, in press-c) administered
to 20 Yale undergraduates verbal analogies that differed from standard analogies
in that the positions of from one to three analogy terms could be occupied by
multiple-choice options. The particular positions that were thus occupied
differed from one item type to another. Either two or three alternative
answer options were substituted for each missing analogy term (see also
Lunzer, 1965). An example of such a problem is MAN : SKIN :: (dog, tree) :
(bark, cat). The correct answers are "tree" and "bark." The complete set
of formats include the following item types, where terms with the subscript
i are missing ones with either two or three answer options substituted for
the missing term: A_i : B :: C : D; A : B_i :: C : D; A : B :: C_i : D; A : B ::
C : D_i; A_i : B :: C_i : D; A_i : B :: C : D_i; A : B_i :: C_i : D; A : B_i :: C : D_i;
A : B :: C_i : D_i; and A : B_i :: C_i : D_i.

Item types from these peripheral paradigms, as well as those from the
central paradigm, form the basis of the task analyses presented in the next
part of the chapter.

Componential Investigations of General Intelligence

We have proposed a metatheoretical framework for theory construction
in a recent chapter (Sternberg, in press-e) that comprises a list of ques-
tions that a complete theory of intelligence ought at least to be able to
address. We shall organize our discussion of our componential investigations
of general intelligence around the questions proposed by this framework.

1. What kind or kinds of problems does the theory address? Any at-
tempt to provide an information-processing account of general intelligence
(or any other kind of account) must start off with an appropriate set of
tasks on the basis of which conclusions about general intelligence will be
drawn. If the set of tasks is inappropriate, obviously, it doesn't matter
much what kind of theorizing follows from it. In our approach, tasks are
·selected on the basis of four criteria originally proposed by Sternberg and
Tulving (1977) in a different context and proposed in the present context
by Sternberg (in press-d): quantifiability, reliability, construct validity,
and empirical validity. The first criterion, quantifiability, assures the
possibility of the "assignment of numerals to objects or events according to
rules" (Stevens, 1951, p. 1). The second criterion, reliability, measures
true-score variation relative to total-score variation. In other words, it
measures the extent to which a given set of data is systematic. The third
criterion, construct validity, assures that the task has been chosen on the
basis of some psychological theory. The theory thus dictates the choice of
tasks, rather than the other way around. The fourth criterion, empirical
validity, assures that the task serves the purpose in the theory that it
is supposed to serve. Thus, whereas construct validity guarantees that
the selection of a task is motivated by theory, empirical validity tests the
extent to which the theory is empirically supportable.

Our choice of tasks in the investigation of general intelligence has
included as its mainstays analogies, series completions, and classifications.
The choice of these tasks was motivated largely by the criteria described
above. First, performance on each of these tasks is readily quantifiable
in terms of solution latency, error rate, response choice, and the like.
Second, performance on these tasks has been reliably measured in countless
tests of mental ability, as well as in a number of information-processing
analyses of human intelligence. Third, the construct validity of these
item types has been demonstrated in multiple ways. Factor analyses of
intelligence-test batteries have shown these three kinds of items to be
among those loading most highly on the general factor (see Cattell, 1971;
Guilford, 1967; Guilford & Hoepfner, 1971; Spearman, 1927; Thurstone, 1938).
These tasks have played a central role in information-processing analyses
of intelligence (see, e.g., Evans, 1968; Greeno, 1978; Mulholland, Pellegrino,
& Glaser, 1980; Pellegrino & Glaser, 1980; Simon, 1976; Sternberg, 1977b, 1979)
as well as in psychometric investigations; and they have even played an impor-
tant role in Piagetian investigations (see, e.g., Piaget, 1972; Piaget with
Montangero & Billeter, 1977). Indeed, the inclusion of these item types in
so many theoretical investigations as well as practical measurements of intel-
ligence strongly attests to their construct validity. Finally, the items
have been shown in correlational analyses (usually presented in technical
manuals for tests) to be highly correlated both with total scores on the test
batteries in which they are contained and with external kinds of performance,
such as school grades (see, e.g., Cattell & Cattell, 1963).

We make no claim that these are the only item types one might have chosen
to study as an entree to the general factor in intelligence, or even that they
are the best item types to study. Another likely candidate, for example, is

the matrix problem, which we interpret as consisting of multiple converging

series completions presented in two dimensions (see, e.g., Hunt, 1974). We

do believe, however, that our set of three tasks comprises an appropriate,

although obviously incomplete, battery on the basis of which one may begin

to analyze the general factor in human intelligence.

2. What performance components are posited by the theory? A theory of

general intelligence should state the performance components involved

(either necessarily or optionally) in solution of the kinds of items dealt

with by the theory. Investigators differ, of course, in where their ideas come from

regarding the components used.   They may do an implicit task analy-

sis by going through a task themselves; they may use verbal reports supplied

by subjects after testing; they may use think-aloud protocols supplied by

subjects during test; or they may use their intuitions to expand or modify

previous theories. Whatever their origin, the performance components should

be specified and described.

The proposed theory posits use of up to seven performance components in

the solution of analogies, series completions, and classification problems.

The components are most easily explicated and their use in the task contexts

shown by some examples of how they might be used in the solution of actual

test problems as might be found on intelligence tests.

Consider as an example the analogy, LAWYER : CLIENT :: DOCTOR : (a.

medicine, b. patient). According to the theory, a subject encodes each term

of the analogy, retrieving from semantic memory and placing in working memory

attributes that are potentially relevant for analogy solution; next, the subject

infers the relation between LAWYER and CLIENT, recognizing, say, that a lawyer

provides professional services to a client; then, the subject maps the higher-

order relation between the first and second halves of the analogy, here recog-

nizing that the first half of the analogy deals with the services of the legal

profession and that the second half of the analogy deals with the services of

the medical profession; next, the subject applies the relation inferred between

the first two terms from the third analogy term, here, DOCTOR, to form an

ideal point representing the ideal solution to the analogy; then, the subject

compares answer options, seeking the ideal solution from among the answers pre-

sented; if none of the answer options corresponds to the ideal point, the

subject must justify one of the answer options as preferable to the others,

in that it is closest to the ideal point; in a rank-ordering task, multiple

justifications may be needed as successive options are eliminated; finally,

the subject responds with the chosen answer.

The same basic model can be extended to series completion problems. Con-

sider, for example, the series completion, TRUMAN : EISENHOWER : (a. F.

Roosevelt, b. Kennedy). The subject must encode each term of the series com-

pletion. Next, he or she infers the relation of succession between TRUMAN

and EISENHOWER. Mapping is not necessary in this and other series problems,

because there is no distinction between domain and range: All terms of the

problem derive from a single, homogeneous domain, here, that of presidents

of the United States. The subject must, however, apply the relation inferred

between TRUMAN and EISENHOWER from EISENHOWER to an ideal point, presumably,

Kennedy. Next, the subject compares the answer options, seeking the one cor-

responding to the ideal point. If neither option (or in the case of more than

two options, none of the options) corresponds to the ideal point, the subject

justifies one option as closest to the ideal point. Suppose, for example,

that option (b) was L. Johnson rather than Kennedy. This option would be

preferable to F. Roosevelt, in that it names a successor to EISENHOWER, but

would be nonideal, in that it does not name an immediate successor. Finally,

the subject responds with the chosen answer. As in the case of analogies, the

rank-ordering task would require multiple justifications to determine which option is closest to the ideal point, of those options not yet ranked.

The model can also be extended to classification problems. Consider, for example, the problem, NEBRASKA, CALIFORNIA, VERMONT, (a. Texas, b. Reno). The subject must encode each term of the problem. Next, the subject must infer what is common to NEBRASKA, CALIFORNIA, and VERMONT, in essence seeking a prototype or centroid that abstracts what is common to the three terms; as was the case in the series completion problems, the subject need not map any higher-order relation, since all of the terms of the problem are from a single, homogeneous domain. In classification problems, application is also unnecessary, because the inferred centroid is the ideal point: The subject need not extrapolate in any way to seek some further ideal point. Next, ·the subject compares the answer options, seeking the ideal solution. If none is present, the subject justifies one option as closer to the ideal point than the other(s). Finally, the subject responds. As in the case of analogies and series completions, rank-ordering the options requires multiple executions of the justification component. Ranking in these problems and in the series completions proceeds according to a decision rule to be described.

The components of information processing in the three tasks are slightly different: The analogies task requires the full set of seven information-processing components; the series completion task requires a subset of six of the seven parameters in the analogies task; the classification task requires a subset of five of the six parameters in the series completion task. Thus, one would expect that for problems with terms of equal difficulty, analogies would be slightly more difficult than series completion problems, and series completion problems would be slightly more difficult than classification problems. In fact, mean latencies follow this predicted pattern.

The performance components described above are posited to be suffi-
cient for describing the flow of information processing from the beginning
to the end of task solution. Each contributes in some amount to the
latency and difficulty of a given task item. In order to account for
subjects' choices of response alternatives, it is necessary to supplement
these components with a decision rule for option selection. The decision
rule we use, following Rumelhart and Abrahamson (1973), is Luce's (1959)
choice axiom. We further propose, as did Rumelhart and Abrahamson, that
relative rankings of answer options follow a negative exponential decay
function, with the form of the decay function in part determined by the
representation of information that is used. We shall describe our im-
plementation of the rule further in the next section on representation.

3. **Upon what representation or representations do these components act?**
We doubt that there is any known test that is reasonably conclusive in dis-
tinguishing one form of representation from another. We therefore tend to
assume our representations, and accept as indirect evidence supporting them
the fits of process or response-choice models that are based upon these
representations.

We believe that the form of representation a subject uses in solving
a problem depends in part upon the content of the particular problem, and in
part upon the subject's own preferences. In a standard item from an intelli-
gence test, such as the analogy WASHINGTON : 1 :: LINCOLN : (a. 10, b. 5),
for example, we believe subjects are likely to use an attribute-value repre-
sentation. In such a representation, WASHINGTON might be encoded as
[(president (first)), (portrait on currency (dollar)), (war hero (Revolutionary))] ,
1 might be encoded as [(counting number (one)), (ordinal position (first)),
(amount (one unit))], LINCOLN might be encoded as [(president (sixteenth)),

(portrait on currency (five dollars)), (war hero (Civil))], and so on. The

attribute-value representation can be extended to pictorial as well as verbal

kinds of items. A black square inside a white circle, for example, might

be represented as [((shape (square)), (position (surrounded)), ((color (black))),

((shape (circle)), (position (surrounding)), ((color (white))) .

In our joint research on mammal-name analogies, we have assumed the

spatial representation of mammal names used by Henley (1969), Rips, Shoben,

and Smith (1973), and Rumelhart and Abrahamson (1973). The conceptual basis

for the use of this representation in reasoning was first provided by these

last investigators. Rumelhart and Abrahamson suggested that reasoning occurs

when information retrieval depends upon the form of one or more relationships

among words (or other units). Pursuing this definition of reasoning, these

investigators claimed that probably the simplest possible reasoning task is

the judgment of the similarity or dissimilarity between concepts. They

assumed that the degree of similarity between concepts is not directly stored

as such, but is instead derived from previously existing memory structures.

Judged similarity between concepts is a simple function of the "psychological

distance" between these concepts in the memory structure. The nature of this

function and of the memory structure upon which it operates is clarified by

their assumptions (after Henley, 1969) that (a) the memory structure may

be represented as a multidimensional Euclidean space and that (b) judged

similarity is inversely related to distance in this space.

On this view, analogical reasoning (and, as we shall show, other forms

of reasoning as well) may itself be considered to be a kind of similarity

judgment, one in which not only the magnitude of the distance but also

the direction is of importance. For example, we would ordinarily interpret

the analogy problem, $A : B :: C : X_i$, as stating that A is similar to B in

exactly the same way that C is similar to X_i. According to the assumptions

outlined above, we might reinterpret this analogy as saying that the directed

or vector distance between $\underline{A}$ and $\underline{B}$ is exactly the same as the vector distance

between $\underline{C}$ and $\underline{X}_i$. The analogy is imprecise to the extent to which the two

vector distances are not equal.

Rumelhart and Abrahamson formalized the assumptions of their model by

stating that given an analogy problem of the form $A : B :: C : (X_1, X_2, \ldots, X_n)$,

it is assumed that

> A1. Corresponding to each element of the analogy problem there is a
> point in an m-dimensional space....
>
> A2. For any analogy problem of the form $A : B :: C : ?$, there exists a
> concept I such that $A : B :: C : I$ and an ideal analogy point, denoted $\underline{I}$
> such that $\underline{I}$ is located the same vector distance from $\underline{C}$ as $\underline{B}$ is from $\underline{A}$. The
> coordinates of $\underline{I}$ are given by the ordered sequence $\{\underline{c}_j + \underline{b}_j - \underline{a}_j, \; \underline{j} = 1, m.$
>
> A3. The probability that any given alternative $\underline{X}_i$ is chosen as the best anal-
> ogy   solution from the set of alternatives $\underline{X}_1, \ldots, \underline{X}_n$ is a monotonic
> decreasing function of the absolute value of the distance between the point
> $\underline{X}_i$ and the point $\underline{I}$, denoted $|X_i - I|$. (p. 4)

The first assumption simply states that the concepts corresponding to the

elements of the analogy exist and are locatable within the $\underline{m}$-dimensional

space representing the memory structure. The second assumption states that

an ideal solution point also exists within the memory structure, and that this

point also represents a concept; it is quite likely that the ideal point may

not have a named mammal in the English (or any other) language. The third

assumption states that the selection of a correct answer option is governed

by the distance between the various answer options and the ideal point, such

that less distant answer options are selected more often than are more distant

answer options.

These assumptions permit ordinal predictions about the goodness of the various answer options, but do not permit quantitative predictions. In order to make quantitative predictions of response choices, Rumelhart and Abrahamson made assumption 3 more specific, and added two more assumptions:

3'. The probability that any given alternative X_i is chosen from the set of alternatives $X_1,\ldots,X_n$ is given by $Pr(X_i|X_1,\ldots,X_n) = p_i = v(d_i) / \sum_j^n v(d_j)$, where v( ) is a monotonically decreasing function of its argument.

4. $v(x) = \exp(-\alpha X)$, where X and α are positive numbers.

5. We assume that the subjects rank a set of alternatives by first choosing the Rank 1 element according to 3' and, then, of the remaining alternatives, deciding which is superior by application of 3' to the remaining set and assigning that Rank 2. This procedure is assumed to continue until all alternatives are ranked. (pp. 8-9)

The more specific version of assumption 3 (labeled 3') is an adoption of Luce's (1959) choice rule to the choice situation in the analogy. Assumption 4 further specifies that the monotone decrease in the likelihood of choosing a particular answer option as best follows an exponential decay function with increasing distance from the ideal point. The model of response choice therefore requires a single parameter, α, representing the slope of the function. Rumelhart and Abrahamson actually had their subjects rank-order answer options. The investigators predicted the full set of rank orderings by assuming (in assumption 5) that once subjects had ranked one or more options, they would rank the remaining options in exactly the same way that they had ranked the previous options, except that they would ignore the previously ranked options in making their further rankings. Rumelhart and Abrahamson (1973) carried out three ingenious experiments that lent credence to their response-choice model of analogical reasoning.

We proposed a modest extention of the Rumelhart-Abrahamson model so that it could account for response choices in series completion and classification problems as well as in analogy problems. Figure 1 shows how the extended model accounts for response choices in each of the three types of problems.

Insert Figure 1 about here

Consider an analogy problem of the form, A : B :: C : (D_1, D_2, D_3, D_4), where the subject's task is to rank-order the answer options in terms of how well their relation to C is parallel to that between B and A. In an analogy problem such as this one, the subject must find an ideal point, $\underline{I}$, that is the same vector distance from $\underline{C}$ as $\underline{B}$ is from $\underline{A}$. Having found this point, the subject rank-orders answer options according to their overall Euclidean distance from the ideal point. The probability of selecting any one answer option as best is assumed to follow an exponential decay function, with probability decreasing as distance from the ideal point increases. The same selection rule is applied in rank-ordering successive options, with previously selected options removed from consideration.

Consider next a series completion problem of the form, A : B : (C_1, C_2, C_3, C_4), where the subject's task is to rank-order the answer options in terms of how well they complete the series carried from A to B. Here, the subject must find an ideal point, $\underline{I}$, that is the same vector distance from $\underline{B}$ that B is from A. Note that the difference between a series completion problem and an analogy is that whereas the terms of an analogy form a parallelogram (or its m-dimensional analogue) in the multidimensional space, the terms of a series completion form a line segment (or its m-dimensional analogue) in the space. The same principle would apply, regardless of the number of terms in the item stem. Having found the ideal point, the subject rank-orders answer options with respect to the ideal

point in just the same way that he or she would in an analogy problem.

Consider finally a classification problem of the form, A, B, C, (D_1, D_2, D_3, D_4), where the subject's task is to rank-order the answer options in terms of how well they fit with the three terms of the item stem. In this type of problem, the subject must find an ideal point, $\underline{I}$, that represents the centroid in multidimensional space of $\underline{A}$, $\underline{B}$, and $\underline{C}$. Having found this point, the subject rank-orders the answer options according to their overall Euclidean distance from the ideal point, in just the same way as he or she would for analogies or series completions. Again, the same basic principle applies without regard to the number of terms in the item stem. The centroid of the points is theorized always to serve as the ideal point.

Thus, we believe that the spatial representation can be used, at least 'in the context of terms falling into a semantic field, to represent information in a way that is suitable for the solution of three of the main types of problems used to measure general intelligence--analogies, series completions, and classifications.

4. By what strategy or strategies are the components combined? Strategy refers to the order and mode in which components are executed. By "mode," we refer to whether the execution of a given set of components is serial or in parallel, exhaustive or self-terminating, and independent or nonindependent. In serial processing, components are executed sequentially; in parallel processing, they are executed simultaneously. In exhaustive processing, all possible executions of a given component or set of components are performed; in self-terminating processing, execution of components terminates before all possible executions have occurred. In independent processing, the execution of a given component has no effect upon whether any other component is executed; in dependent processing, execution of one component does affect whether one or

more other components are executed.

In the Sternberg-Gardner experiments, we addressed the question of strategy only at a rather global level. The tests of the process model (in Experiment 2) were designed primarily to identify the components subjects actually used in solving the problems, rather than to identify how these components were combined. Our best evidence indicates that for the analogies, subjects would (a) encode the first term, (b) encode the second term, (c) infer the relation between the two terms, (c) encode the third term, (d) map the higher-order relation from the first half of the analogy to the second, (e) apply the previously inferred relation as mapped to the second half of the analogy to generate an ideal solution, (f) encode the two answer options, (g) compare the options, (h) justify one of the options as preferred, if nonideal, and (i) respond. For the series completions, we believe subjects would (a) encode the first term, (b) encode the second term, (c) infer the relation between the two terms, (d) apply the inferred relation to generate an ideal solution, (e) encode the two answer options, (f) compare the options, (g) justify one of the options as preferred, if nonideal, and (h) respond. For the classifications, subjects would (a) encode the first term, (b) encode the second term, (c) encode the third term, (d) infer the centroid, (e) compare the two answer options, (f) justify one of the options as preferred, if nonideal, and (g) respond.

More penetrating analyses of subjects' strategies were conducted in the analogical-reasoning experiments of Sternberg (1977a), Sternberg and Nigro (1980), and Sternberg and Rifkin (1979). These analyses enabled us to form detailed process models for the solution of each type of analogy. A flow chart representing the strategy most often used by adults for a wide variety of analogy types (schematic-picture, verbal, geometric) would show that

subjects encode and infer as many attributes as they can find (exhaustive information processing), but map, apply, compare, and justify only a limited number of attributes (self-terminating processing). Subjects execute the self-terminating components in a self-terminating loop whereby they map, apply, and compare a single attribute at a time, seeking to disconfirm all but one answer option and then to justify one as acceptable; if the loop does not yield a satisfactory solution the first time around, it is iterated, this time with a second attribute. The process continues until it is possible to select one answer as the best of the given ones. Note that in this strategy, all components are assumed to be executed serially, and there is heavy process dependence in the sense that the outputs of earlier component executions are needed for later component executions. We have never actually compared serial versus parallel models of task performance, being convinced that the comparison is an extremely difficult one to carry out (see Pachella, 1974).

5. What are the durations, difficulties, and probabilities of component execution? Table 2 shows parameter estimates for latencies of each component that was common to each of the three tasks studied in the Sternberg-Gardner experiments (except for inference, which was not statistically reliable in all three cases). If the three tasks truly involve the same components of information processing, then the parameter estimates should be equal within a margin of error of estimation across tasks. A one-way analysis of variance was conducted across tasks upon each of the four parameter estimates of interest. Only the value of the justification parameter differed significantly across tasks (at the .001 level). Hence, the data are consistent with the notion that at least three of the components are common in kind across tasks, although obviously, further tests are needed. Justification could still be common across tasks but differentially difficult to execute, so that the existence of a significant

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Insert Table 2 about here

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difference does not totally refute the claim that the components are the same.

Values of latency components differ, of course, with item content and format.

We found, for example, that component latencies are generally lower for simple

schematic-picture analogies than for simple verbal analogies, and lower for

the verbal analogies than for geometric ones. What is of greatest interest

is the relative amounts of time the various components consume. Encoding

is always quite time-consuming, and the proportion of time it consumes is

directly proportional to the complexity of the stimulus terms. The latency

of response is about the same for different kinds of analogies, although the

estimated parameter may differ as a function of other components that are

sometimes confounded with response. (This confounding happens because response

is estimated from the regression constant, which includes within it any source

·of latency that is common across all of the item types.) The amounts of time

devoted to the other components vary greatly with analogy type, although it

has been found that even small discrepancies between the ideal solution and

the best of the given answer options can result in fairly substantial amounts

of time spent in justifying this answer option as best, although nonideal

(Sternberg, 1977a, 1977b).

Sternberg (1977a, 1977b) predicted error rates as well as latencies for

item solution. The finding of major interest was that self-terminating com-

ponents were largely responsible for the errors that were made in item solu-

tion. In other words, the time saved by terminating information processing early

is paid for in terms of the greater frequency of errors that are made due

to what turns out to be premature termination of processing.

Sternberg and Gardner (1980) estimated . as 2.52 for analogies, 2.56

for series completions, and 2.98 for classifications. Although these values

did differ significantly from each other (due, obviously, to the higher value

of α for the classification task), they are certainly in the same ballpark, and even the most extreme value corresponds roughly to that obtained by Rumelhart and Abrahamson for their analogies, 2.91.

The fits of the proposed theory to the various kinds of data were generally quite good in all of the experiments. In the Sternberg (1977a, 1977b) experiments, values of R^2 between predicted and observed latencies were .92, .86, and .80 for schematic-picture, verbal, and geometric analogies respectively. Values of R^2 were .85 and .89 respectively in the Sternberg-Nigro (verbal analogies) and Sternberg-Rifkin (schematic-picture analogies) experiments. And values of R^2 were .77, .67, and .61 for the analogies, series completions, and classifications in the Sternberg-Gardner experiment. For the model of response choice in this study, the values of R^2 were .94, .96, and .98 for analogies, series completions, and classifications, respectively.

6. What metacomponents are used in this form of information processing? We have proposed six metacomponents that we believe are critical in understanding intelligent information processing (Sternberg, in press-e):

(1) Recognition of just what the problem is that needs to be solved. Anyone who has done research with young children knows that half the battle is getting the children to understand just what is being asked of them. Communication can also be a problem with adults, of course. Indeed, Resnick and Glaser (1976) have argued that intelligence is in large part the ability to learn in the absence of direct or complete instruction. Distractors on intelligence tests are frequently chosen so as to be the right answers to the wrong problems, so that they are chosen by those who do not recognize the problem that has been presented to them.

We found a rather striking example of the operation (or failure to operate) of this metacomponent in our developmental study with schematic-picture analogies (Sternberg & Rifkin, 1979). In this experiment, certain second-graders consistently circled as correct one or the other of the first two analogy terms, rather than one or the other of the last two terms that constituted the answer options. We were puzzled by this systematic misunderstanding until we put together three facts--(a) that we were testing children in a Jewish parochial school, (b) that the children normally did their lessons in English in the morning and in Hebrew in the afternoon, and that (c) we happened to be doing our testing in the afternoon. Apparently, some of these young children perseverated in their normal afternoon right-to-left visual scanning, even in a task presented in English and where it was .explicitly stated that the options were at the right. In the verbal analogies exper-iment of Sternberg and Nigro (1980), we also found a failure in the operation of this metacomponent: Some of the younger children (third and sixth graders) used association between words heavily in solving analoiges, despite the fact that the task was presented as an analogical reasoning task.

(2) Selection of lower-order components. An individual must select a set of lower-order (performance, acquisition, retention, or transfer) components to use in the solution of a given task. Selection of a nonoptimal set of components can result in incorrect or inefficient task performance. In some instances, choice of components will be partially attributable to dif-ferential availability or accessibility of various components. For example, young children may lack certain components that are necessary or desirable for the accomplishment of particular tasks, or may not yet execute these com-ponents in a way that is efficient enough to facilitate task solution.

Two examples of changes in the selection of metacomponents with age come from our research on the development of analogical reasoning. First, we have found that young children (in Piagetian terms, those who are not yet formal-operational or even transitional into this period of development) do not map higher-order relations between the two halves of an analogy in their solution of analogy items. The mapping component is apparently either unavailable or inaccessible to such children (Sternberg & Rifkin, 1979). Comparable results have been found by others as well (see, e.g., Piaget with Montangero and Billeter, 1977). Second, we have found that whereas younger children are quite prone to use an associative component in their solution of analogies, older children (those who are well into formal-operational thinking) do not (Sternberg & Nigro, 1980). Again, these results are consistent with those of others (see, e.g., Achenbach, 1970, 1971).

(3) Selection of a strategy for combining lower-order components. In itself, of course, a set of components is insufficient to perform a task: The components must be combined into a strategy. Strategy selection, like component selection, depends in part upon developmental level. In our developmental research on analogies, for example, we have found that children tend to modify their strategy for solving analogies as they grow older such that the strategy becomes increasingly more nearly exhaustive. The tendency to become more nearly exhaustive in information processing applies both within and between terms of analogies: Older children are more likely to encode as many attributes of each analogy term as they can and to infer as many relations between attributes of the first two analogy terms as they can than are younger children (Sternberg & Rifkin, 1979); the older children are also more likely to search through all of the answer options in a given analogy, rather than choosing an answer as soon as they see an option that seems potentially appropriate (Sternberg & Nigro, 1980).

(4) <u>Selection of one or more representations or organizations for</u>

<u>information</u>. A given component is often able to operate upon any one of a

number of different possible representations or organizations for information.

The choice of representation or organization can facilitate or impede the

efficacy with which the component operates. In our research on the develop-

ment of analogical reasoning, we have found evidence of changes in represen-

tation with age. Specifically, younger children are more likely to encode

each of the attributes of a schematic-picture analogy separably, and then

to make comparisons on each of the individual attributes; older children

are more likely to integrate attributes and to treat the schematic pictures

in a configural way (Sternberg & Rifkin, 1979, Experiment 2). We have also

found at least tentative evidence of individual differences in representations

in adults. In our animal-name reasoning studies, we found that some individuals

were more prone to use overlapping clusters of animal terms in addition to

spatial dimensions than were others. For example, such a person might try

to facilitate their analogy solution by realizing that animals like a tiger,

lion, and panther are related in terms of dimensions such as size, ferocity,

and humanness, but also in their all being jungle animals. Cats and dogs,

on the other hand, are domesticated pets. But a household cat is related to

the jungle animals by virtue of its being a feline animal, whereas a dog is not.

The idea, then, is that animals are interrelated in a network of overlapping

clusters that complements their dimensional attributes.

(5) <u>Decision regarding allocation of componential resources</u>. One of the

barriers problem solvers encounter in solving problems is in the processing

capacity they can bring to bear on a problem. Given that one's resources are

limited, one must decide how many resources one can bring to bear on any given

problem, given that there are usually competing demands for these resources.

An example of differential resource allocation in action can be seen in our research on analogies with both children and adults. First, as children grow older, their latencies for analogy solution decrease. However, this composite latency can be decomposed into a series of component latencies that show that the global result is a gross oversimplification of what happens in analogy solution. It turns out that older subjects spend relatively more time than do the younger subjects in encoding the stimulus terms, but relatively less time in operating upon these encodings (Sternberg & Rifkin, 1979, Experiment 1). Apparently, the older children realize that obtaining a good fix on the nature of the stimulus later enables one to process that stimulus more efficiently, and thereby to save time, overall. Second, better adult reasoners solve analogy problems more quickly than do poorer adult reasoners. But this result, too, is an oversimplification. Complementary to the developmental finding is one that among adults, better reasoners tend to spend more time in encoding analogy terms than do poorer reasoners, but less time in operating upon these encodings (Sternberg, 1977a, 1977b). Thus, more sophisticated allocation of componential resources results in an overall improvement in performance.

(6) Solution monitoring. As individuals proceed through a problem, they must keep track of what they have already done, what they are currently doing, and what they still need to do; the relative importances of these three items of information may differ across problems, but nevertheless, all must be accomplished to some extent in every problem. That younger children are often less apt at solution monitoring than are older children is seen in the tendency of some of the second-graders in the pictorial analogies experiment to circle one of the two analogy terms at the left rather than the right of the problem (Sternberg & Rifkin, 1979). Almost all of the second-graders were

able to solve most analogies successfuly, given that they understood what to do.

The insensitivity of these subjects to the fact that right-to-left solution

almost never yielded a suitable solution, much less, a suitable analogy,

can be viewed as a failure of these subjects to monitor their solution

processes adequately.

Even very young children do monitor their solutions to some extent, how-

ever. The use of solution monitoring in even the reasoning of very young child-

dren can be seen in the metacomponential decision of children of as young as

the third-grade level to use a justification component in the solution of

verbal analogies. The component continues to be used throughout the age

span to adulthood. This performance component is elicited upon the recog-

nition by a subject that none of the presented answer options in a multiple-

.choice analogy provides an ideal completion for the given problem. In such

an event, the subject may have to justify one of the presented options as

nonideal, but superior to the alternative options. The justification component

is something of a "catchall," in that it includes in its latency any reexecution

of previously executed performance components that may be attempted in an effort

to see whether a mistaken intermediate result has been responsible for the

subject's failure to find an optimal solution. The decision to use this com-

ponent reflects an awareness on the part of the subject that things are not going

quite right: The path to solution has reached a deadend, and some route must

be found that will yield an ideal answer, or else an answer must be selected

that is acceptable, if nonideal.

(7) What are the effects of (a) problem format, (b) problem content, and

(c) practice upon intellectual performance? All of these variables have effects

upon intellectual performance, at least in reasoning by analogy. Consider,

for example, the effect of true-false versus multiple-choice format. In

true-false analogies, solution can be quite simple if analogies are essentially
digital in character, by which we mean that an answer is clearly either right
or wrong. In schematic-picture analogies, for example, specific attributes
such as height, clothing color, sex, and weight of pictures of people might
be manipulated: The correct answer would be one that had the appropriate
values on each of these four attributes. Suppose that one is asked instead
to solve verbal analogies, however. It is actually quite rare that any
given fourth term will be precisely correct; indeed, it is not even clear
what "precisely correct" means for verbal analogies. For example, is HAPPY :
SAD :: TALL : SMALL a true analogy or a false one? Usually, SHORT rather than
SMALL is contrasted antonymously to TALL. Whereas SMALL does not seem quite
right, it doesn't quite seem wrong either. Or consider the analogy, CAR : GAS
:: PERSON : FOOD. Obviously, the two lower-order relationships (between CAR
and GAS and between PERSON and FOOD) that comprise this analogy are parallel
in some ways, but not in others. On what basis could one say whether the analogy
is "true" or "false," however? In multiple-choice analogies, the situation is
different. On the one hand, one's task is complicated by the fact that it is
now necessary to eliminate several incorrect options, some of which may be quite
close to the best answer, rather than merely to indicate whether a given answer
is correct or not; on the other hand, one's task is to choose the best answer,
not the right answer. One can select an option knowing full well that it is
not right or ideal in any meaningful sense of these terms, but that it is the
best of the options that have been presented. The sources of difficulty are
thus changed considerably when one moves from true-false to forced-choice
analogical reasoning (Sternberg, 1977b).

The effects of problem content are sometimes hard to predict in advance.
Sternberg (1977a, 1977b), for example, found that people handle verbal and geometric

analogies in surprisingly similar ways. Sternberg and Rifkin (1979), however, found that two kinds of schematic-picture analogies that on their face look quite similar are processed in quite different ways. Analogies with clearly separable attributes are processed with maximum self-termination by adult subjects; analogies with attributes that are integral are processed with a combination of self-terminating and exhaustive information-processing components.

Consider finally the effects of practice upon analogy solution. Sternberg (1977b) compared performance during a first session of schematic-picture analogy solution to performance during a fourth (and final) session. As would be expected, latencies and error rates decreased from the first session to the fourth. All components showed shorter latencies during the fourth session than during the first except for inference. There was no evidence of strategy change across sessions: Fits of the various models and variants of models were almost identical in the two different sessions. The most interesting difference showed up during external validation of scores: In the first session, no correlations of latencies for the analogy items with scores on reasoning tests were significant; in the fourth session, more than half of the correlations were significant, and many of them were of high magnitude, reaching into the .60s and .70s. Results such as these led Glaser (1967) to conclude that psychometric test scores are more highly correlated with performance after asymptote is reached than with performance during initial trials of practice.

8. What are the salient sources of individual differences in intellectual performance at a given age level? The major loci of individual differences in intellectual performance in the componential approach to intelligence reside in the various kinds of components of human intelligence. Each component of each kind potentially can generate individual differences in performance. Sternberg

(1977b) found substantial individual differences in the speeds at which the various performance components of analogical reasoning are executed, and in the degree to which subjects used any systematic strategy at all. No substantial individual differences were found in components or forms of representation used (although Sternberg & Gardner did find evidence of such representational differences). In terms of strategy differences, the main source of variation was that some adults seemed to be self-terminating in their inference process, although most were apparently exhaustive in this process.

9. What are the salient sources of individual differences in intellectual performance across age levels (i.e., in intellectual development)? We believe that the most important sources of developmental differences are metacomponential ones. Indeed, the section on metacomponents (No. 6) showed developmental trends in all of the metacomponents considered. On this view, the major source of development is in executive planning and decision making in problem solving. We have also found developmental differences in rates and accuracies of component execution (e.g., Sternberg, 1979a, 1980 ; Sternberg & Nigro, 1980; Sternberg & Rifkin, 1979). But the significance of these changes for development seems much smaller than the significance of the metacomponential changes, and indeed, we believe that these differences are attributable in large part to metacomponential changes. More efficacious planning and decision-making enable problem solvers to become more rapid and accurate in their problem solving. Consider, for example, the large decrease in error rates that have been observed in our developmental studies of analogical reasoning. Earlier analyses (Sternberg, 1977b) had shown that errors in analogy solution were due almost entirely to premature self-termination of information processing. This finding, coupled with the finding that children

become more nearly exhaustive in their information processing with increasing age, suggest that the tendency to become more nearly exhaustive may account at least in part for the developmental decrease in error rates that is observed.

10. Relationships between components of various intellectual tasks. Individual parameter estimates were not reliable in the Sternberg-Gardner study, so it was not feasible to intercorrelate them. Intercorrelations were computed, however, between mean response latencies for subjects for each pair of data sets: The correlations were .85 between analogies and series completions, .86 between analogies and classifications, and .88 between series completions and classifications. A principal-components factor analysis of the three sets of latencies revealed a strong general factor in the individual-differences data, with the first, unrotated principal component accounting for 91% of the variance in the data. Had the tests shown no overlap in individual-differences variation (zero intercorrelations), this factor would have accounted for only 33% of the variation. The data are thus consistent with the notion that a single real-time information-processing model might apply across tasks.

A comparable set of analyses was performed on the ability-test scores: Here, the correlations were .72 between analogies and series completions, .45 between analogies and classifications, and .65 between series completions and classifications. A principal-components factor analysis of the three sets of test scores (numbers correct) revealed an unrotated, general first factor accounting for 74% of the variance in the individual-differences data. Again, such a factor would have accounted for only 33% of the variation had the tasks been unrelated. These results, too, therefore, are consistent with the notion of common processes across tasks.

Finally, intercorrelations were computed between task scores across the two

forms of task presentation (tachistoscopic, leading to response latencies,

and pencil-and-paper, leading to numbers correct). Correlations across task

format were lower than those within format, as would be expected if there

were at least some medium-specific variance that were not shared across

task formats. Such medium-specific variance might result from differences

across task formats in speed-accuracy tradeoffs, in attentional allocations

for items presented singly (as in a tachistoscopic task) and for items pre-

sented as a group (as in a pencil-and-paper task), in kinds of strategy or

other planning required, or in what is measured by latency and accuracy scores.

The correlations ranged from -.21 to -.41, with a median for the nine inter-

task correlations of -.35 ($p < .05$). Correlations of tasks with their analogues

across formats (e.g., tachistoscopic analogies with pencil-and-paper

were only trivially higher than correlations of nonanalogous tasks across

formats (e.g., tachistoscopic analogies with pencil-and-paper series completions :

The median correlation for analogous tasks was -.35 ($p < .05$), whereas the median

correlation for nonanalogous tasks was -.30 ($p < .05$). A factor analysis of

the six tasks (three tachistoscopic and three pencil-and-paper) yielded a

first, unrotated principal component accounting for 57% of the variance in

the data. If tests were unrelated, a value of 17% would have been expected.

As expected, the second unrotated principal component, accounting for 26% of

the variance in the data, was a bipolar factor distinguishing pencil-and-paper

tasks from response-latency ones. The general factor unifying the various kinds

of tasks was thus about twice as strong as the medium-specific factor differen-

tiating the two task formats. Subsequent factors were of little interest.

11. What are the relationships between the components of the set of intellectual tasks of interest and general intelligence? Sternberg (1977b) found that each of the major components in analogical reasoning--inference, mapping, application, justification--can correlate with performance on tests of general intelligence when the attributes of the analogies being solved are nonobvious. As would be expected, faster latencies were associated with higher test performance. The latency of the response component was also very highly correlated with IQ test scores, although this finding was given a metacomponential interpretation: Metacomponents constant across the item types were at least partly responsible for the high correlation between the regression constant and the test scores (see Sternberg, 1979b). Finally, encoding was also correlated with test scores, but in the opposite direction (as mentioned earlier): Slower encoding was associated with higher reasoning abilities. This finding, too, was interpreted metacomponentially as indicating a strategy whereby slower encoding was associated with faster operations upon the better encodings that resulted, so that overall performance was facilitated. Many of these findings have since been replicated (e.g., Mulholland, Pellegrino, & Glaser, 1980).

12. What are the practical implications of what we know about the forms of intellectual behavior covered by the given theory? We have devised a training program for the metacomponents and performance components described earlier that we hope to implement in the near future (see Sternberg, in press-c). To date, we have done research only on training the performance components of analogical reasoning (see Sternberg, Ketron, & Powell, in press). We have found that it is possible to train people to use various different strategies for solving analogies, and that strategy training can greatly reduce correlations between component latencies and measured intelligence.

Sternberg (1977b) has argued that inductive reasoning such as that measured by series completions, classifications, and especially analogies is pervasive in everyday experience. "We reason analogically whenever we make a decision about something new in our experience by drawing a parallel to something old in our experience. When we buy a new pet hamster because we liked our old one or when we listen to a friend's advice because it was correct once before, we are reasoning analogically" (p. 99).

Oppenheimer (1956) has pointed out the signal importance of analogy in scientific reasoning of the kind done by scientists and even nonscientists on an everyday basis:

> Whether or not we talk of discovery or of invention,
> analogy is inevitable in human thought, because we
> come to new things in science with what equipment we
> have, which is how we have learned to think, and above
> all how we have learned to think about the relatedness
> of things. We cannot, coming into something new, deal
> with it except on the basis of the familiar and old-
> fashioned. The conservatism of scientific enquiry is not
> an arbitrary thing; it is the freight with which we
> operate; it is the only equipment we have. (pp. 129-130)

Analogical reasoning also plays an important role in legal thinking, where it may be called "reasoning by example" (Levi, 1949):

> The basic pattern of legal reasoning is reasoning by example.
> It is reasoning from case to case. It is a three-step process
> described by the doctrine of precedent in which a proposition
> descriptive of the first case is made into a rule of law and
> then applied to a next similar situation. The steps are these:
> similarity is seen between cases; next the rule of law inherent
> in the first case is announced; then the rule of law is made
> applicable to the second case. This is a method of reasoning
> necessary for the law, but it has characteristics which under
> other circumstances might be considered imperfections. (pp. 1-2)

Consider, in general, how the metatheoretical framework described in this chapter might be applied to diagnostic and prescriptive problems in educational and everyday theory and practice.

Suppose we know that a certain child is a poor reasoner. We might know this because of the child's low scores on psychometric tests of reasoning ability or because the child performs poorly in school on problems requiring various kinds of reasoning. The kinds of analyses suggested here yield a number of indices for each child (or adult) that can help localize the source of difficulty. These sources correspond to the basic sources of individual differences described earlier. One can discover whether certain components needed to solve one or more kinds of intellectual problems are unavailable, or available but not accessed when needed; whether the child is using a sub-optimal strategy, that is, one that is time-consuming, inaccurate, or unable to yield any solution at all; whether the child finds execution of certain components especially difficult or time-consuming; whether the child is incon-sistent in his or her use of strategy; or whether the child fails in meta-componential decision-making about problem solution. This information can the be used to prescribe the kind of remediation needed by the child.

Summary

To summarize, general intelligence can be understood componentially as deriving in part from the execution of general components in information processing behavior. Most general components are metacomponents, although performance, acquisition, retention, and transfer components also can be general in nature. Metacomponents dominate the information-processing sys-tem because they are the source of all direct activation of other kinds of components and because only they receive direct feedback from other kinds of components, as well as among themselves.

Componential metatheory requires a theory of general intelligence to deal with twelve questions about the nature of intelligence and its interaction with the real world. These questions were posed, and answers were given based on the research we and our colleagues have done using various componential techniques. The proposed theory was able at least to provide tentative answers to all of these questions.

We wish to emphasize in closing that we know, as should others, that our account of general intelligence is limited to one level of analysis, and is incomplete in many respects. We believe, for example, that the functioning of general intelligence in the real world cannot be understood completely without reference to the motivational variables that drive intellectual functioning, and hence that any account of general intelligence that is wholely cognitive (as is ours) cannot account for all of the behavioral patterns that we can reasonably label as "generally intelligent" (see also Zigler, 1971). Hence, we present our account as one step toward a more all-encompassing theory that will view intelligence in all of its multifarious aspects.

References

Achenbach, T. M. The children's associative responding test: a possible

alternative to group IQ tests. Journal of Educational Psychology,

1970, 61, 340-348.

Achenbach, T. M. The children's associative responding test: a two-year

followup. Developmental Psychology, 1971, 5, 477-483.

Butterfield, E. C., & Belmont, J. M. Assessing and improving the executive

cognitive functions of mentally retarded people. In I. Bialer & M. Stern-

licht (Eds.), Psychological issues in mental retardation. New York:

Psychological Dimensions, 1977.

Campione, J. C., & Brown, A. L. Toward a theory of intelligence: Contributions

from research with retarded children. In R. J. Sternberg & D. K. Detterman

(Eds.), Human intelligence: Perspectives on its theory and measurement.

Norwood, N.J.: Ablex, 1979.

Carroll, J. B. Psychometric tests as cognitive tasks: A new "structure of intel-

lect." In L. B. Resnick (Ed.), The nature of intelligence. Hillsdale, N.J.:

Erlbaum, 1976.

Carroll, J. B. Individual difference relations in psychometric and experimental

cognitive tasks. (NR 150-406 ONR Technical Report: Final Report.) Chapel

Hill, N.C.: L. L. Thurstone Psychometric Laboratory, University of North

Carolina, 1980.

Cattell, R. B. Abilities: Their structure, growth, and action. Boston:

Houghton-Mifflin, 1971.

Cattell, R. B., & Cattell, A. K. S. Test of g: Culture Fair, Scale 3. Champaign,

Illinois: Institute for Personality and Ability Testing, 1963.

Egan, D. E. Accuracy and latency scores as measures of spatial information

processing (Research report No. 1224.). Pensacola, Florida: Naval

Aerospace Medical Research Laboratories, 1976.

Evans, T. G. A program for the solution of geometric-analogy intelligence

   test questions. In M. Minsky (Ed.), Semantic information processing.

   Cambridge, Mass.: M.I.T. Pre-s, 1968.

Eysenck, H. J. The structure and measurement of intelligence. Berlin:

   Springer-Verlag, 1979.

Glaser, R. Some implications of previous work on learning and individual

   differences. In R. M. Gagné (Ed.), Learning and individual differences.

   Columbus, Ohio: Merrill, 1967.

Greeno, J. B. Natures of problem-solving abilities. In W. K. Estes (Ed.),

   Handbook of learning and cognitive processes (Vol. 5). Hillsdale, N.J.:

   Erlbaum, 1978.

Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill, 1967.

Guilford, J. P., & Hoepfner, R. The analysis of intelligence. New York:

   McGraw-Hill, 1971.

Henley, N. M. A psychological study of the semantics of animal terms. Journal

   of Verbal Learning and Verbal Behavior, 1969, 8, 176-184.

Horn, J. L. Organization of abilities and the development of intelligence.

   Psychological Review, 1968, 75, 242-259.

Humphreys, L. B. The construct of general intelligence. Intelligence, 1979,

   3, 105-120.

Hunt, E. B. Quote the raven? Nevermore! In L. W. Gregg (Ed.), Knowledge

   and cognition. Hillsdale, N.J.: Erlbaum, 1974.

Hunt, E. B. Mechanics of verbal ability. Psychological Review, 1978, 85,

   109-130.

Hunt, E. B., Lunneborg, C., & Lewis, J. What does it mean to be high verbal?

   Cognitive Psychology, 1975, 7, 194-227.

Jensen, A. R. g: Out moded theory or unconquered frontier? Creative Science

and Technology, 1979, 2, 16-29.

Jensen, A. R. The chronometry of intelligence. In R. J. Sternberg (Ed.), Advances
in the psychology of human intelligence (Vol. 1). Hillsdale, N.J.: Erlbaum,
in press.

Keating, D. P., & Bobbitt, B. L. Individual and developmental differences in
cognitive-processing components of mental ability. Child Development,
1978, 49, 155-167.

Kruskal, J. B. Multidimensional scaling by optimizing goodness of fit to a
nonmetric hypothesis. Psychometrika, 1964, 29, 1-27. (a)

Kruskal, J. B. Nonmetric multidimensional scaling: A numerical method.
Psychometrika, 1964, 29, 28-42. (b)

Levi, E. H. An introduction to legal reasoning. Chicago: University of
Chicago Press, 1949.

Luce, R. D. Individual choice behavior. New York: Wiley, 1959.

Lunzer, E. A. Problems of formal reasoning in test situations. In P. H. Mussen
(Ed.), European research in cognitive development. Monographs of the
Society for Research in Child Development, 1965, 30(2, Serial No. 100),
19-46.

McNemar, Q. Lost: Our intelligence? Why? American Psychologist, 1964, 19,
871-882.

Mulholland, T. M., Pellegrino, J. W., & Glaser, R. Components of geometric
analogy solution. Cognitive Psychology, 1980, 12, 252-284.

Newell, A., & Simon, H. A. Human problem solving. Englewood Cliffs, N.J.:
Prentice-Hall, 1972.

Oppenheimer, J. R. Analogy in science. American Psychologist, 1956, 11, 127-135.

Pachella, R. G. The interpretation of reaction time in information processing
research. In B. Kantowitz (Ed.), Human information processing: Tutorials
in performance and cognition. Hillsdale, N.J.: Erlbaum, 1974.

Pellegrino, J. W., & Glaser, R. Components of inductive reasoning. In R. E.
Snow, P.-A. Federico, & W. Montague (Eds.), Aptitude, learning, and instruct:

Cognitive process analysis. Hillsdale, N.J.: Erlbaum, 1980.

Piaget, J. The psychology of intelligence. Totowa, New Jersey: Littlefield, Adams, 1972.

Piaget,, J. (with Montangero, J., & Billeter, J.). Les correlats. L'Abstraction réfléchissante. Paris: Presses Universitaires de France, 1977.

Resnick, L. B., & Glaser, R. Problem solving and intelligence. In L. B. Resnick (Ed.), The nature of intelligence. Hillsdale, N.J.: Erlbaum, 1976.

Rips, L., Shoben, E., & Smith, E. Semantic distance and the verification of semantic relations. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 1-20.

Rumelhart, D. E., & Abrahamson, A. A. A model for analogical reasoning. Cognitive Psychology, 1973, 5, 1-28.

Shepard, R. N. The analysis of proximities: Multidimensional scaling with an unknown distance function. I. Psychometrika, 1962, 27, 125-140. (a)

Shepard, R. N. The analysis of proximities: Multidimensional scaling with an unknown distance function. II. Psychometrika, 1962, 27, 219-246. (b)

Shepard, R. N. Representation of structure in similarity data: Problems and prospects. Psychometrika, 1974, 39, 373-421.

Simon, H. A. Identifying basic abilities underlying intelligent performance of complex tasks. In L. Resnick (Ed.), The nature of intelligence. Hillsdale, N.J.: Erlbaum, 1976.

Snow, R. E. Theory and method for research on aptitude processes. In R. J. Sternberg & D. K. Detterman (Eds.), Human intelligence: Perspectives on its theory and measurement.

Spearman, C. 'General intelligence,' objectively determined and measured. American Journal of Psychology, 1904, 15, 201-293.

Spearman, C. The abilities of man. London: Macmillan, 1927.

Sternberg, R. J. Component processes in analogical reasoning. Psychological

Review, 1977, 84, 353-378. (a)

Sternberg, R. J. Intelligence, information processing, and analogical reasoning:

The componential analysis of human abilities. Hillsdale, N.J.: Erlbaum,

1977. (b)

Sternberg, R. J. Componential investigations of human intelligence. In A.

Lesgold, J. Pellegrino, S. Fokkema, & R. Glaser(Eds.), Cognitive

psychology and instruction. New York: Plenum, 1978. (a)

Sternberg, R. J. Isolating the components of intelligence. Intelligence, 1978,

2, 117-128. (b)

Sternberg, R. J. Developmental patterns in the encoding and combination of

logical connectives. Journal of Experimental Child Psychology, 1979, 28,

469-498. (a)

Sternberg, R. J. The nature of mental abilities. American Psychologist, 1979,

34, 214-230.

Sternberg, R. J. The development of linear syllogistic reasoning. Journal of

Experimental Child Psychology, 1980, 29, 340-356. (a)

Sternberg, R. J. Representation and process in linear syllogistic reasoning.

Journal of Experimental Psychology: General, 1980, 109, 119-159. (b)

Sternberg, R. J. Toward a unified componential theory of human intelligence:

I. Fluid abilities. In M. Friedman, J. Das, & N. O'Connor (Eds.),

Intelligence and learning. New York: Plenum, 1980. (c)

Sternberg, R. J. Factor theories of intelligence are all right almost.

Educational Researcher, in press. (a)

Sternberg, R. J. Instrumental and componential approaches to intelligence and

its training. Proceedings of a Conference on Thinking and Learning Skills.

Pittsburgh, in pre . (b)

Sternberg, R. J. Intelligence and nonentrenchment. _Journal of Educational_

Psychology, in press. (c)

Sternberg, R. J. Reasoning, problem solving, and intelligence. In R. J.

Sternberg (Ed.), _Handbook of human intelligence._ New York: Cambridge

University Press, in press. (d)

Sternberg, R. J. Sketch of a componential subtheory of human intelligence.

Behavioral and Brain Sciences, in press. (e)

Sternberg, R. J. Conway, B. E., Ketron, J. L., & Bernstein, M. People's

conceptions of intelligence. Paper presented at the annual meeting of

the American Psychological Association, Montreal, September, 1980.

Sternberg, R. J. & Gardner, M. K. Unities in inductive reasoning. (NR150-412 ONR

Report No. 18.) New Haven: Department of Psychology, Yale University,

1980.

Sternberg, R. J., Ketron, J. L., & Powell, J. S. Componential approaches to

the training of intelligent performance. _Intelligence_, in press.

Sternberg, R. J., & Nigro, G. Developmental patterns in the solution of verbal

analogies. _Child Development_, 1980, _51_, 27-38.

Sternberg, R. J., & Rifkin, B. The development of analogical reasoning processes.

Journal of Experimental Child Psychology, 1979, _27_, 195-232.

Sternberg, R. J., & Salter, W. Stalking the elusive homunculus: Isolating

the metacomponents of intelligence. Manuscript in preparation, 1980.

Sternberg, R. J., & Tulving, E. The measurement of subjective organization

in free recall. _Psychological Bulletin_, 1977, _84_, 539-556.

Stevens, S. S. Mathematics, measurement and psychophysics. In S. S. Stevens

(Ed.), _Handbook of experimental psychology_. New York: Wiley, 1951.

Thurstone, L. L. _Primary mental abilities_. Chicago: University of Chicago

Press, 1947.

Thurstone, L. L. _Multiple factor analysis_. Chicago: University of Chicago

Press, 1947.

Vernon, P. E. The structure of human abilities. London: Methuen, 1971.

Zigler, E. The retarded child as a whole person. In H. E. Adams & W. K.

Boardman, III (Eds.), Advances in experimental clinical psychology

(Vol. 1). New York: Pergamon Press, 1971.

Footnote

Table 1

Examples of Problems Used in Mammal Names Reasoning Experiments

Problem Type	Experiment	
	Response Choice	Response Time
Analogy	TIGER : CHIMPANZEE :: WOLF : (a. RACCOON, b. CAMEL, c. MONKEY, d. LEOPARD)	TIGER : CHIMPANZEE :: WOLF (a. RACCOON, b. MONKEY)
Series Completion	SQUIRREL : CHIPMUNK : (a. RACCOON, b. HORSE, c. DOG, d. CAMEL)	SQUIRREL : CHIPMUNK : (a. HORSE, b. CAMEL)
Classification	ZEBRA, GIRAFFE, GOAT, (a. DOG, b. COW, c. MOUSE, d. LEOPARD)	ZEBRA, GIRAFFE, GOAT, (a. MOUSE, b. LEOPARD)

Table 2

Parameter Estimates for Latency Components

Parameter	Task	Parameter Estimate
	Analogies	1.22
Encoding	Series Completions	1.00
	Classifications	.79
	Analogies	.13
Comparison	Series Completions	.14
	Classifications	.14
	Analogies	.36
Justification	Series Completions	.18
	Classifications	.24
	Analogies	1.36
Response+	Series Completions	3.36
	Classifications	2.93

Note: Parameter estimates, expressed in seconds, are unstandardized linear

regression coefficients. Comparison was estimated as a "time savings"

for greater distance, but is expressed here in unsigned form. All

coefficients are statistically significant at the 5% level or better.

Figure Caption

Figure 1. Schematic diagrams showing rules for arriving at ideal point, I, in each of three induction tasks. In analogies, I is located as the fourth vertex in a parallelogram having A, B, and C as three given vertices. In series completions, I is located as the completion of a line segment that is at the same vector distance from B that B is from A. In classifications, I is the centroid of the triangle with A, B, and C as vertices. The rules can be extended to n dimensions by assuming n-dimensional analogues to the two-dimensional figures depicted. In each type of problem, options are presented at successively greater Euclidean distances from the ideal point.

Analogy
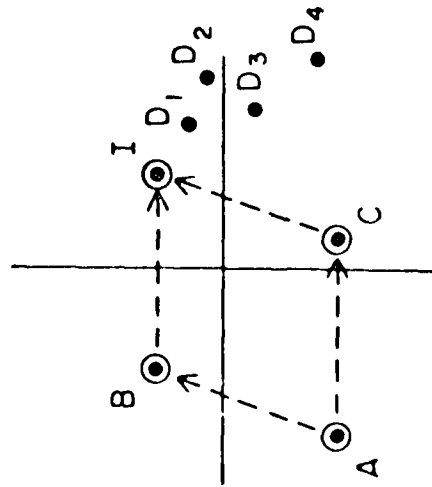
Series Completion
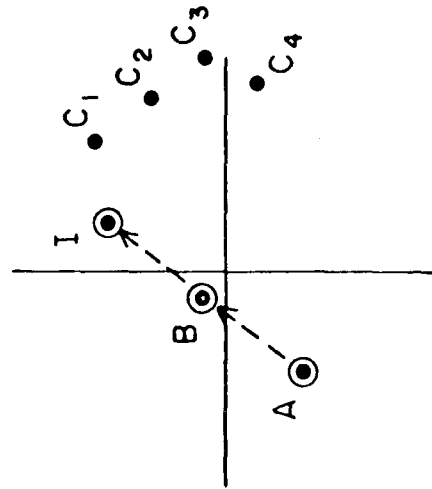
Classification

Technical Reports Presently in this Series

NR 150-412, ONR Contract N0001478C0025

No.	Name	Published Reference
1	Intelligence Research at the Interface between Differential and Cognitive Psychology. January, 1978.	Sternberg, R. J. Intelligence research at the interface between differential and cognitive psychology. Intelligence. 1978, 2, 195-222.
2	Isolating the Components of Intelligence. January, 1978.	Sternberg, R. J. Isolating the components of intelligence. Intelligence, 1978, 2, 117-128.
3	Deductive Reasoning. January, 1978.	Sternberg, R. J., Guyote, M. J., & Turner, M. E. Deductive reasoning. In R. E. Snow, P.-A. Federico, & W. Montague (Eds.), Aptitude, learning and instruction: Cognitive process analysis (Vol. 1). Hillsdale, N.J.: Erlbaum, 1980.
4	Toward a Unified Componential Theory of Human Reasoning. April, 1978.	Sternberg, R. J. Toward a unified componential theory of human intelligence: I. Fluid ability. In M. Friedman, J. Das, & N. O'Connor (Eds.), Intelligence and learning. New York: Plenum, 1980.
5	A Transitive-Chain Theory of Syllogistic Reasoning. April, 1978.	UNPUBLISHED TO DATE
6	Components of Syllogistic Reasoning. April, 1978.	Sternberg, R. J., & Turner, M. E. Components of syllogistic reasoning. Acta Psychologica, in press.
7	Metaphor, Induction, and Social Policy: The Convergence of Macroscopic and Microscopic Views. April, 1978.	Sternberg, R. J., Tourangeau, R., & Nigro, G. Metaphor, induction, and social policy: The convergence of macroscopic and microscopic views. In A. Ortony (Ed.), Metaphor and thought. New York: Cambridge University Press, 1979.
8	A Proposed Resolution of Curious Conflicts in the Literature on Linear Syllogisms. June, 1978.	Sternberg, R. J. A proposed resolution c curious conflicts in the literature on linear syllogisms. In R. Nickerson (Ed. Attention and performance VIII. Hillsdale, N.J.: Erlbaum, 1980.
9	The Nature of Mental Abilities. June, 1978.	Sternberg, R. J. The nature of mental abilities. American Psychologist, 1979, 34, 214-230.

Technical Reports Presently in this Series

NR 150-412

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No.	Name	Published Reference

10 Psychometrics, Mathematical Psychology, and Cognition: Confessions of a Closet Psychometrician. June, 1978.

UNPUBLISHABLE.

11 Understanding and Appreciating Metaphors, June, 1978.

UNPUBLISHED TO DATE.

12. Representation and Process in Transitive Inference. October, 1978.

Sternberg, R. J. Representation and process in linear syllogistic reasoning. Journal of Experimental Psychology: General, 1980, 109, 119-159.

13 Aptness in Metaphor. October, 1978.

Tourangeau, R., & Sternberg, R. J. Aptness in metaphor. Cognitive Psychology, in press.

14 Contrasting Conceptions of Intelligence and their Educational Implications. November, 1978.

Sternberg, R. J. Factor theories of intelligence are all right almost. Educational Researcher, in press.

15 An Aptitude-Strategy Interaction in Linear Syllogistic Reasoning. April, 1979.

Sternberg, R. J., & Weil, E. M. An aptitude-strategy interaction in linear syllogistic reasoning. Journal of Educational Psychology, 1980, 72, 226-234.

16 Intelligence Tests in the Year 2000: What Forms will they Take and what Purposes will they Serve? April, 1979.

Sternberg, R. J. Six authors in search of a character: A play about intelligence tests in the year 2000. Intelligence, 1979, 3, 281-291.

17 New Views on IQs: A Silent Revolution of the 70s. April, 1979.

Sternberg, R. J. Stalking the I.Q. quark. Psychology Today, 1979, 13, 42-54.

18 Unities in Inductive Reasoning. October, 1979.

UNPUBLISHED TO DATE.

19 Components of Human Intelligence. October, 1979.

Sternberg, R. J. Sketch of a componential subtheory of human intelligence. Behavioral and Brain Sciences, In press.

20 The Construct Validity of Aptitude Tests: An Information-Processing Assessment. October, 1979.

Sternberg, R. J. The construct validity of aptitude tests: An information-processing assessment. ...

No.	Name	Published Reference
20 (Continued)		A. P. Maslow, R. H. McKillup, & M. Thatcher (Eds.), Construct validity in psychological measurement. Princeton: Educational Testing Service, in press.
21	Evaluation of Evidence in Causal Inference. October, 1979.	Schustack, M. W., & Sternberg, R. J. Evaluation of evidence in causal inference. Journal of Experimental Psychology: General, in press.
22	Componential Approaches to the Training of Intelligent Performance. April, 1980.	Sternberg, R. J., Ketron, J. L., & Powell, J. S. Componential approaches to the training of intelligent performance. Intelligence, in press.
23	Intelligence and Nonentrenchment. April, 1980.	UNPUBLISHED TO DATE.
24	Reasoning, Problem Solving, and Intelligence. April, 1980.	Sternberg, R. J. Reasoning, problem solving, and intelligence. In R. J. Sternberg (Ed.), Handbook of human intelligence. New York: Cambridge University Press, in press.
25	Claims, Counterclaims, and Components: A Countercritique of Componential Analysis. June, 1980.	Sternberg, R. J. Claims, counterclaims, and components: A countercritique of componential analysis. Behavioral and Brain Sciences, in press.
26	Interaction and Analogy in the Comprehension and Appreciation of Metaphors. October, 1980.	UNPUBLISHED TO DATE.
27	The Nature of Intelligence. October, 1980.	Sternberg, R. J. The nature of intelligence. New York University Education Quarterly, in press.
28	People's Conceptions of Intelligence. October, 1980.	Sternberg, R. J., Conway, B. E., Ketron, J. L., & Bernstein, M. People's conceptions of intelligence. Journal of Personality and Social Psychology: Attitudes and Social Cognition, in press.

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No.	Name	Published Reference
29	Nothing Fails Like Success: The Search for an Intelligent Paradigm for Studying Intelligence.	Sternberg, R. J. Nothing fails like success: The search for an intelligent paradigm for studying intelligence. Journal of Educational Psychology, in press.
30	Reasoning with Determinate and Indeterminate Linear Syllogisms.	NOT YET PUBLISHED.
31	A Componential Interpretation of the General Factor in Human Intelligence.	Sternberg, R. J., & Gardner, M. K. A componential interpretation of the general factor in human intelligence. In H. J. Eysenck (Ed. A model for intelligence. Berlin: Springer, in press.

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